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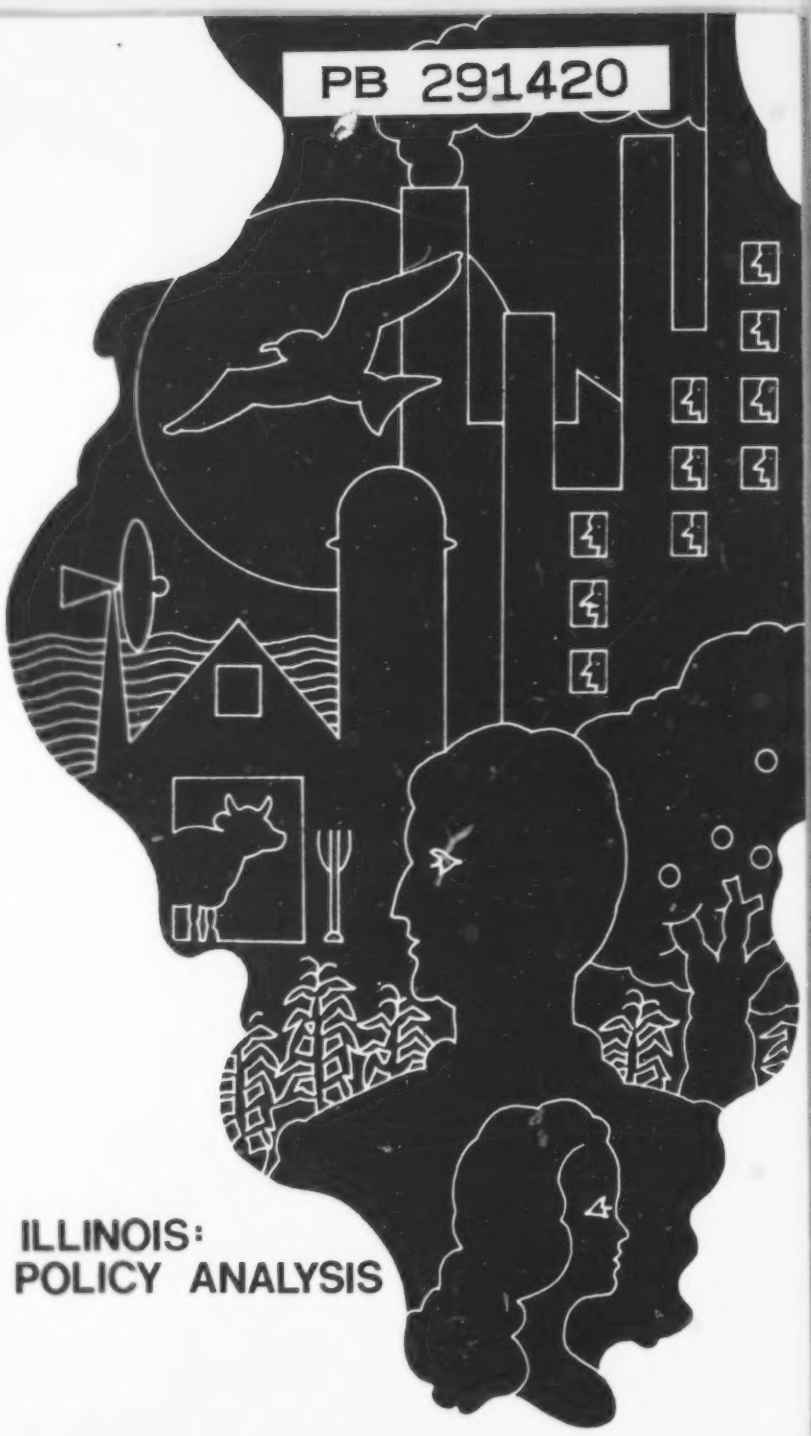

USED OIL RECYCLING IN ILLINOIS: A REVIEW AND PUBLIC POLICY ANALYSIS

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Between 80 and 100 million gallons of industrial oils are purchased by Illinois industries annually. Their use results in the disposal of approximately 50-80 million gallons of potentially recoverable used oil.[1] The major consequences of current disposal practices are large scale losses of a valuable dwindling resource, and the potential for improper disposal methods. In view of these consequences it is the aim of this report to examine alternative state policies which would encourage more widespread industrial used oil recovery.

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by

John J. Yates
Harriet P. Croke

ETA Engineering, Inc.
Westmont, Illinois 60559

and

Kevin G. Croke
Consultant

PROJECT OFFICER: Peter Loquercio
Project No. 80.085

Frank Beal, Director

Peter Loquercio, Director
Division of Environmental
Management

State of Illinois
Institute of Natural Resources
309 West Washington Street
Chicago, IL 60606

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Illinois Institute for Environmental Quality
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1.0 Introduction

Between 80 and 100 million gallons of industrial oils are purchased by Illinois industries annually. Their use results in the disposal of approximately 50-80 million gallons of potentially recoverable used oil.[1] The major consequences of current disposal practices are large scale losses of a valuable dwindling resource, and the potential for improper disposal methods. In view of these consequences it is the aim of this report to examine alternative state policies which would encourage more widespread industrial used oil recovery.

Interest in developing policies regarding used oil reuse is now widespread. Federal studies show great potential energy savings if used oil can be recovered as a lubricant. Other countries such as Germany have recognized that incentives for used oil recycling and re-refining should be part of a national policy while states such as California have taken positive steps to encourage its reuse as both a conservation and environmental protection measure. The efforts in the United States and Europe to channel used oil back into the economy in environmentally accepted ways, have included: 1) educational programs aimed at inducing citizens or industries to deliver used oil to central collection sites; 2) licensing procedures to assure that the used oil is being disposed of or recycled in an acceptable manner; 3) public investments in recycling operations, and 4) financial incentives through changes in tax laws to promote recycling. The results of employing these policies can be dramatic. For example, the German economy recovers and reuses a much larger percentage of recoverable oil that the United States does.

The questions arising from any consideration of regulatory or economic initiatives in the area of used oil include: 1) How is the oil being disposed of presently? Are present practices creating an environmental hazard? 2) What federal and state regulatory structure exists at present which may provide incentives or disincentives toward increased recovery of used industrial oil? 3) What are the benefits and costs of new state policies regarding the disposal or recycling of industrial used oil?

To answer these questions the following steps were taken:

1) A survey was sent to relevant industries in Illinois to determine quantities and modes of used oil disposal,
2) Tests were run on used oil obtained from Illinois industries to determine types of contaminants, in an effort to evaluate its recovery potential,
3) current and pending Federal regulations were examined to determine what incentives or disincentives they contained for used oil recovery,
4) used oil regulations in other states were explored for effectiveness and impact,
5) a profile of potential Illinois initiatives to improve disposal and recovery practices was developed.

The industrial survey results, the laboratory analysis of used oil samples and a thorough review of used oil recycling and disposal practices in Illinois are presented in the first part of this used oil study. Study conclusions and a review of some of the information developed in

this first phase of the analysis are presented in Section 2, 3 and 4 of this report. Section 5 presents a survey of Federal and State used oil legislation. Section 6 suggests certain industrial used oil State policy options outlining specific State actions, oil recovery mechanisms and the costs and benefits to Illinois.

2.0 Current Used Oil Disposal and Current Recycling Practices

The major methods of disposal of industrial oils can be classified as:

1) Fuel supplement - the re-refining or blending of used oil with virgin oil for combustion,
2) Incineration - the combustion of oil for the purposes of volume reduction,
3) Land spreading - surface spreading of waste oil on soil,
4) Deposition on landfill - mixing of oil with solid wastes for burial on landfill,
5) Road oiling and dust control - the spreading of oil on roads principally in order to reduce fugitive dust emissions,
6) Disposal in lagoons,
7) Sewage disposal - dumping of used oil-water mixtures into sewer systems,
8) Injection in deep wells - injection of oil in wells which are deep enough to assure that ground water supplies would not be endangered,
9) Recycling the processing of used industrial oils to a point where they can be re-employed for their original uses.

The environmental significance of these practices arises from the potential of used oil to: 1) pollute the air with toxic substances (including lead); 2) contaminate ground water supplies, if improperly disposed of by a landfill or road oiling; and 3) impair the operation of sewage treatment plants, if illegally dumped in sewers.

Environmental regulations and shifts in markets have changed and continue to change disposal practices. Disposal to sewers and waterways without treatment is prohibited although complete enforcement of such regulations is still difficult. Disposal in landfills, of oil which cannot be reused in any manner, is increasing due to the emergence of water related environmental controls.

The markets for re-refined and recycled products are also shifting. Several factors affecting the market for used oil reuse in the last decade have reduced the incentive to recycle oil as lubricant. Changes in the Federal Excise Bill of 1965 have removed favorable tax benefits from the use of recycled oil while Federal Trade Commission Regulations have depressed the recycled oil market by requiring product identification that the oil had been previously used, rather than performance characteristics, e.g., contamination levels, viscosity pour point, etc. The designation of an oil as used or recycled lowers its desirability in the perception of prospective customers. Current federal procurement procedures based on Department of Defense specifications bar the purchase of re-refined oil regardless of its chemical or physical properties. In sum, these factors have weakened the market for the recycling of oil to the extent that production has dropped nationally from 225 million to 50

million gallons per year in the last decade. On the other hand, the increase in fuel prices by nearly 300% has increased the use of used oil as fuel, often without sufficient safeguards for the environmental hazards of the resulting combustion products.

3.0 Inventory of Industrial Used Oils in Illinois

To assess the benefits of an industrial used oil management program in Illinois, it is necessary to develop an estimate of used oil volumes produced in the state. Unfortunately, relatively little data are available to support such an estimate. U.S. Department of commerce figures (see Table 3-1) only provide an indication of the sales of oils in Illinois, not the volumes of used oils resulting from their use.

The most significant sources of used oil are the primary metal and metal-working industries, and the transportation sector. To estimate the volume of used oil produced as a result of these activities, a variety of "used oil factors" have been derived. (A used oil factor is an empirical ratio of the used oil produced by a process, to the virgin oil input to that process). The overall factor that is generally reported is 0.50. However, this figure really does not represent the actual production of used oil. Very little oil is actually consumed in use, but the 0.50 figure provides some indication of the quantities of oils which might relatively easily be recovered for recycling.

In Illinois, the State Environmental Protection Agency and the Liquid Waste Control Association can account for less than 8 million gallons of oil-based waste, which may account for about 4% of recorded

Table 3-1

Sales of Lubricating and Industrial Oils In Illinois

	Oils Liters x 10^3 (Gallons x 10^3)				
				Industrial	
	Total	Automotive	Aviation	Lubricating	Other
1973	670,134 (177,050)	290,354 (76,712)	1,011 (267)	253,016 (66,847)	125,753 (33,224)
1975	547,265 (144,588)	254,110 (67,136)	1,147 (303)	179,693 (47,475)	112,316 (29,674)

Source: "Sales of Lubricating and Industrial Oils and Greases", issued November, 1977, U.S. Department of Commerce, Bureau of the Census. These figures are the latest published information.

oil purchases. This figure represents that amount which is legally transported and disposed of at licensed landfills. A significant fraction of this quantity consists of water and solvents.

Due to this lack of information on used oil flows, an Illinois industrial used oil survey was conducted as part of this study (with the aid of the Illinois Manufacturers Association).[1] A questionnaire was constructed to survey industries in Standard Industrial Classification (SIC) categories 33 through 38. A list of the SIC categories surveyed is provided in Table 3-2. These industries use nearly all of the industrial oils sold in Illinois.

Table 3-2

SIC Category	Description
33	Primary metals industries
34	Fabricated metal products, except ordnance, machinery and transportation equipment
35	Machinery, except electrical
36	Electrical machinery, equipment and supplied
37	Transportation equipment
38	Professional, scientific and controlling instruments; photographic and optical goods; watches and clocks

Two hundred and twenty-five questionnaires were returned, of which 194 included sufficient information for analysis.

3.1 Projection of Statewide Used Oil Stream

One of the results from a statistical analysis of survey data was a correlation between employment, type of industrial activity, oil purchase and disposal levels. A set of oil use factors based on employment was

derived for each major industrial sector addressed by the survey. Combined with employment data from the 1972 census of manufacturers for Illinois, these factors were then applied to project statewide estimates of oil use and disposal in each sector.

3.1.1 Used Oil Generation

The disposal fractions of oils purchased derived from survey results range from as low as 0.09 to as high as 0.59 (with an overall average of about 0.30); these values are probably underestimates. A materials balance analysis indicated that the overall disposal fraction is likely to be nearer to 0.90. That is, about 90% is potentially recoverable, but perhaps half of all purchased industrial oils can be relatively easily recycled with present technology. The apparent discrepancy between the survey results and independent estimates of the disposal fraction may be attributed to the fact that the survey showed that most industrial oil users do not maintain comprehensive records of used oil disposal.

Survey results indicate that more than half of the total used oil stream is water. Because water content has a significant influence on both the cost and techniques for recycling and disposal, it is not surprising that of the perhaps 15 million gallons of used industrial oil which is re-refined or reprocessed each year in Illinois, a large contribution is derived from the used oil with low water content.

3.1.2 Used Oil Segregation and Storage Practices

One of the requirements for effective recovery of used oil is to segregate it from other industrial waste liquids and water. To accomplish

this, however, it may be necessary to install storage facilities for the segregated oils. Survey results show that most plants do not segregate their used oils. More than half of the responding plants maintain used oil storage facilities of some kind, but these are not, in general, intended to support reuse programs. Rather, they serve as holding tanks for disposal of waste liquids. The estimated total statewide storage capacity for used oils is 4.3 million gallons. Used oil is stored for an average of 26 days. Since most of the estimated storage capacity is associated with waste liquid disposal rather than used oil recovery, it is fairly safe to assume, as the survey indicates, that oil segregation and storage of these separated oils for recycling is not widely practiced by Illinois industry.

3.1.3 Used Oil Transportation and Disposal

About 90% of the total oily waste stream is handled by commercial haulers who pick up and dispose of the liquid for a fee.[1] Certain of these haulers will pay the industrial source for used oil of sufficiently high quality (low water and sediment content) that it can be reprocessed economically. For the most part however, the commercial hauler collects a fee of from 1-10¢ per gallon for removing and disposing of the liquid.

Survey results show that the method by which commercial haulers dispose of the used oil picked up from their industrial clients depends on the water content. Low water content oil is carried to used oil processors, while the bulk of the high water content liquid is disposed at landfills. Approximately 2 million gallons of the used oil generated on-site is utilized as a fuel supplement by Illinois industrial plants.

Many lubricants, hydraulic, and straight cutting oils are now recycled in plants. If the quantities reused are compared to the quantities originally purchased, it is clear that reuse programs are far from pervasive in Illinois industry. Most of the oil recovered as a result of in-plant reuse programs is recycled by means of settling, water extraction, centrifugal or filtration processes.

3.1.4 Survey Conclusions

From this analysis several observations may be drawn with respect to the patterns of used oil reuse and disposal in Illinois:

1) A relatively small fraction of oil purchased (30%) can be accounted for with respect to its reuse or disposal in the industrial plant.
2) Firms generally consider used oil in terms of a nuisance, to be disposed of by commercial haulers.
3) Industry is generally unaware of the fate of used oil once it leaves the plant (about 40% of the survey respondents did not know the fate of used oil they committed to commercial haulers).
4) Only a small fraction of used oil is recycled.
5) A large fraction of used oil is apparently disposed of at landfills by haulers.*
6) Storage and segregation of industrial used oils for the purposes of recycling are not widespread.

* Many of those industrial plants responding to the survey may be incorrect in thinking that their commercially hauled oil is being taken to the landfill, often it is given or sold to a reprocessor or fuel dealer.

7) A wastewater problem is closely tied with used oil disposal problems due to the high water content of nonsegregated used industrial oils.

4.0 Analysis of Industrial Used Oil Samples

The cost and feasibility of reusing or recycling a used oil is dependent on its physical and chemical properties and the extent to which it contains environmentally harmful contaminants. It is technically feasible to process some used oils to the extent that they are equivalent to virgin oil. By removal of sediment, water, and other contaminants such as trace metals, used oil can be burned as a fuel - either directly or mixed with virgin oil. Similar processing should take place before the used oil is employed for dust control or road oiling, but often only large particulate matter is removed to prevent spray nozzle clogging.

To determine the physical and chemical properties of used oils that are typical of Illinois industry, 85 used oil samples drawn from sources throughout the state were analyzed. The analyses were performed by the laboratories of the University of Illinois, the Motor Oils Refining Co. and the Environmental Clearing House Organization (ECHO).

All of the used oil samples analyzed for this survey were obtained from industries within Standard Industrial Classifications (SIC) 33-37.

The physical tests performed on these samples included measurements of:

A) API Gravity - related to specific gravity at 60^{o} F,

B) Flash Point & Fire Point - the flash point is the temperature at which vapor from heated oil will be ignited by an open

flame; the fire point is the temperature at which the oil becomes ignited and burns for 5 seconds,

C) Pour Point - temperature at which oil will just flow under standardized conditions,

D) Viscosity - resistance of oil to flow

E) Bottom Sediment and Water - measurement of the amount of separable water and sediment per volume of oil.

The chemical tests performed on the oil samples included measurements of:

A) Carbon Residue - % of material incombustible above 1000^{o}F; this test shows the level of deposits which will form when burned,

B) Ash Content - % of material incombustible above temperature at which carbonaceous materials oxidize,

C) Sulphur Content - indicates corrosiveness to equipment and, when used as a fuel, pollution potential,

D) Trace Metals - small amounts of contaminant metals,

E) Calorific Value - net energy produced by combustion of oil,

F) Acid Number - acid concentration of oil.

Table A-1 presents a comparison of the mean values of these tests on used oils and Table A-2 presents manufacturer specifications for virgin lubricating and other oils. Table A-3 provides similar information for the trace elements contained in the oil samples.

4.1 Used Oil as a Lubricant

In terms of the properties presented, the following observations regarding the suitability of the tested used oils for lubricating purposes can be made.

1) API Gravity: 60% of the samples had API gravity values within the range of lubricant oils.

2) Ash Content: used oil samples generally were above virgin oils values.

3) Carbon Residue: the mean value of the used oil samples is within the range of virgin lubricant samples.

4) Bottom Sediment and Water: the used oil mean of 15% is much higher than the negligible amounts in virgin oils (indicating used oils would require treatment to reduce sediment and water contaminant levels prior to reuse).

5) Pour Point: the generally acceptable range is $-40^{o}F$ to $5^{o}F$, the used oil mean is well within this range. (If the temperature at which the oil is used can be controlled, higher values do not present a problem).

6) Flash and Fire Points: the mean value for the used oil just satisfies the minimum for lubricants. (For those used oils below the minimum, processing and possibly blending with virgin oils would be required to achieve satisfactory values for lubrication).

7) Viscosity: 95% of the used oils are within the viscosity range of lubricant applications, and thus viscosity is not a

major obstacle to reuse if matched to the specific application range or if blended with virgin stock to meet requirements.

8) Acid Number: the acid number of the used oils is almost invariably well above the range of lubricants. It appears that most of the oils could not be used without first being neutralized.

In evaluating the above observations it is important to recognize the difficulty of determining the lubricating quality of an oil on the basis of a series of laboratory measurements. Many oils can be used as lubricants with less stringent specifications than those cited above. The final proof of acceptability as a lubricant can be obtained only by actual use. In general, used oils cannot be reused directly as lubricants without processing because of their low flash points and high bottom sediment and water content, but many oils are now being recovered through settling and filtration processes which lower bottom sediment and water content, lower carbon residue (important if oil is being reused as a fuel) and affect viscosity, flash, fire and pour points.

4.2 Used Oils as Fuel Supplements

The most important single determinant of the utility of a used oil for fuel is the value of its heat of combustion. Because the heat of combustion of most lubricants (approximately 20,000 BTU/lb) is about the same as for fuel oil, used oils appear to be useful as a fuel supplement. Table B-1 in Appendix B presents a comparison of the specifications for several grades of fuel oil with the used oil sample analyses results, leading to the following observations. (See Appendix A also).

1) Ash Content and Carbon Residue - the mean ash content and carbon residue of the used oil samples are substantially higher than what is required of fuels. Deposits on burners impair combustion efficiency. Filtration, blending with virgin stock, or other processing seems indicated prior to use as a fuel.

2) Bottom Sediment and Water - the BS&W content of used oils tends to be significantly higher than the 2% limit specified for residual fuel oil. Settling and straining or blending would be required prior to use as fuels.

3) Pour Point - in general, the pour point of used oil is sufficiently low to permit its use as a fuel. Since virgin residual oil must generally be heated in order for it to flow readily, a high pour point is not necessarily a serious limitation for a fuel oil.

4) Flash Point - the flash points of the fuel oils range from $38^{o}F$ to $65^{o}F$, well below the minimum of $140^{o}F$ observed for the used oil samples. The higher flash point presents no obstacle to using used oil blended with virgin oil for fuel.

5) Viscosity - with few exceptions, the viscosity of used oil tends to be slightly higher than, but comparable to that of the virgin product.

6) Trace Elements - the presence of sulfur and a variety of trace metals does not affect the performance of used oil as a fuel supplement, but these contaminants might present a health

or environmental hazard when discharged in the flue gas. Dilution with virgin fuel oil may not always solve this environmental problem.

Studies by GCA's Technology Division and the Task Force on Utilization of Waste Lubricating Oils show some of the results of burning used oils. The used oils were used as a virgin fuel supplement, with a maximum of 15% used oil. Results showed that no unusual damage occurred to the equipment and no unusual maintenance was required as a result of the burning of used oils. (Based on limited information, the American Petroleum Institute (API) report also concluded that the flue gases were environmentally safe).

Several other studies conducted to examine the reuse of oil as a fuel, indicate that, in general, it is impractical to burn only used oil without prior treatment because of equipment damage, maintenance problems, and flue gas emissions when used directly. But when used oil is used as a fuel supplement at concentrations up to 25% of the total fuel volume, the results have been satisfactory according to the published reports.*

Table C-1 presents a comparison of the trace element content of virgin residual fuel oil with that of the used oil samples acquired for the present investigation. On the average, the concentrations of sulfur, silver, sodium, aluminum, nickel, silicon, magnesium and vanadium in used oil are comparable to what is characteristic of virgin residual fuel oil. The concentrations of zinc, copper, barium, tin, lead, phosphorous,

* Further testing of stack effluents is now being conducted by the U.S. EPA (Used Oil Recycling Study - ETA Engineering and RECON Systems of Summerville, N.J.).

boron, cadmium and titanium are significantly higher in used oil than in virgin residual fuel oil. Used oil also displays somewhat higher values for chromium, calcium, iron, molybdenum and manganese.

4.3 Conclusions

The physical and chemical characteristics of the used oils sampled from the metalworking industries exhibit a wide range of values. These results indicate that the cost and extent of reprocessing will vary greatly. Low values of flash points, along with high bottom sediment and water, make use of used oils as lubricants unfeasible without treatment. Several plants now reuse their lubricants to some extent after settling, straining, and magnetic removal of some trace metals, etc.

Because the heat of combustion of used lubricating oils is the same as that of virgin fuel oil, the reuse of these oils as a fuel supplement is possible. The high ash content, carbon residue, and bottom sediment and water content may be lowered to a level acceptable for supplemental fuel oil use, by removal of contaminated matter with settling and straining. This treatment, however, would not necessarily reduce the high metal content of the oils.

Much of the oil sampled could be re-refined to yield a base stock equal to a virgin base stock. Significant savings in re-refining costs could be achieved if oils were segregated within the plant and, more importantly, water and solvent streams kept separate from the oil stream.

5.0 Federal and State Used Oil Regulations

The desirability of Illinois initiating new policies aimed at improving the recovery rate of used oil, depends in part on the federal

regulatory environment. Federal legislation, particularly the Resource Conservation and Recovery Act, the Energy Policy and Conservation Act, and a number of congressional proposals, all bear on the benefits and costs of specific State of Illinois used oil programs. An examination of the legislation of other states, as well as pending Illinois regulations, will also aid in assessing the alternative state strategies. This chapter will briefly summarize the more significant federal and state efforts with regard to used oil, in order to lay the foundation for the evaluation of specific policy alternatives in the next section.

5.1 Resource Conservation and Recovery Act (RCRA) and the Energy Policy and Conservation Act (EPCA)

RCRA, an amendment to the Solid Waste Disposal Act, seeks both to strengthen controls over solid (and liquid) waste disposal practices, and to encourage increased recovery and reuse of waste products. Criteria by which substances will be regulated as a hazardous waste relate to their flammability and toxicity. These properties determine the waste hazard potential of the substance. A hazardous substance is defined in Section 1004(5) as any substance which poses a substantial present or potential hazard to human health or environment, when improperly treated, stored, transported, disposed of or otherwise managed, or, that causes a significant contribution to an increase in mortality, or an increase in serious, irreversible or incapacitating illness.

The final status of used oil as a hazardous waste will depend upon the final outcome of regulations promulgated under Subtitle C of RCRA. One hazardous waste criterion which now appears in the draft proposed

regulations, reads that if a material contains substances which exceed by ten times those permitted in drinking water, then the material is considered to be hazardous. If this proposal passes, the laboratory used oil analysis reported in Phase 1 of this study indicates that probably all used oil would be considered a hazardous waste principally because of the cadmium, chromium, and lead concentrations.[1] The exact nature of the waste management plan in Illinois is still under study. The U.S. EPA "State Hazardous Waste Programs" proposed guidelines were published in the Federal Register, Vol. 43, No. 22 - Feb. 1, 1978. It seems likely that any substance considered a hazardous waste under the Resource Recovery Act will be required to be audited by some form of "cradle-to-grave" reporting system. Such a system would require the generators, collectors, and disposers of the hazardous substance, to report its source, transportation, and ultimate fate, in some formal record-keeping procedure.

Also under Section 3004 of RCRA there will be regulations outlining used oil specifications for dust control, road oiling and for oil used as a fuel supplement. These regulations will be written principally in terms of permitted levels of contaminants.[2]

Section 383 of EPCA requires that the Federal Trade Commission prescribe a labeling standard for containers of recycled oil, indicating any particular end use for which a determination of the substantial equivalency between the used oil and virgin oil product has been made. The Federal Trade Commission labeling regulations are to preempt all other labeling rules which address comparative characteristics of recycled oil. The EPA is also required to issue labeling standards "applicable

to containers of new oil, used oil and recycled oil, relating to the proper disposal of such oils after use. The purpose of EPA labeling requirements is "to reduce to the maximum extent practicable, environmental hazards and wasteful practices associated with the disposal of such oils after their use." At this time it appears that there may be a joint labeling effort between the FTC and the EPA.

The emphasis on labeling requirements by the Federal Trade Commission arose, due to the perceived importance that previous changes in FTC labeling requirements had in depressing the used oil recycling industry. Studies are being presently carried out by the National Bureau of Standards to determine if any straighforward tests can be developed to determine the equivalency of recycled used oil and virgin oil in terms of their lubricating properties.

The EPA requirements for the labeling of containers of new, used or recycled oil are directed at the alternative disposal problems associated with oil, rather than the FTC Consumer Protection Program regarding the labeling of performance characteristics. The EPA requirements will therefore have an impact on, not only the economics of recycling lubricating oils, but also, the economic viability of all potential reuse and disposal programs for industrial oils.

The National Bureau of Standards will soon publish a report outlining tests which can be used to establish the "substantial equivalency" of used oil as a fuel. In effect, these testing procedures establish tests for all fuel oils from which the FTC and the EPA will have to write specifications (perhaps based on revised Department of Defense specifications)

and develop labeling requirements. At this time, it appears that NBS will now develop testing procedures for crankcase oils and later for industrial oils. Both of these tasks will be significantly more complicated for lubricants than for fuel oils.

5.2 RCRA and EPCA Procurement Requirements

EPCA requires, under Section 362-C-3, that every proposed state energy conservation plan, in order to be eligible for federal assistance, must include "mandatory standards and policies relating to energy efficiency to govern the procurement practices of such State and its political subdivisions."

RCRA, in turn, requires via Section 6002 that any procuring agency"... shall procure items composed of the highest percentage of recovered materials practicable consistent with maintaining a satisfactory level of competition." RCRA further defines, in Section 1004, #17, "procuring agency" as any federal agency or any state agency or agency of a political subdivision of a state which is using appropriated federal funds for such procurement, or any person contracting with such agency with respect to work performed under such contract.

Products common to both acts, such as recycled oil, tires, and paper must be procured on an energy efficiency/conservation basis under EPCA; moreover if more than $10,000 of federal funds are used cumulatively, the requirements of RCRA must be met. Finally, this section also provides for "... educating persons employed by federal and state governments and private sectors of the economy..." In RCRA, via Section 6002 ((c), (1), (A) and (B)), the recycled oil problem is addressed by requiring agencies to use the product to the maximum extent practicable.

The technological support required to carry out resource and energy conserving procurements are outlined in both acts. RCRA, in Section 5002, provides the mechanisms for state and local agencies to obtain information on materials recovered from waste. This section charges the National Bureau of Standards to publish guidelines for the development of specifications that "... shall pertain to the physical and chemical properties and characteristics of such materials with regard to their use in replacing virgin materials in various industrial, commercial, and governmental uses."

RCRA, via Section 5003, charges the Secretary of Commerce with developing the economic feasibilities, new uses for, and the geographical locations of existing and/or potential markets for recovered materials.

An important point with regard to the procurement of used oil in Illinois and other states, is that states base their specifications primarily on U.S. military specifications for the purchase of fuel and lubricating oils. This is not the case for the purchase of oil for oil spraying since there are no federal specifications or guidelines for this application (Illinois does have road oiling specifications developed by the Illinois Dept. of Transportation). Most state purchasing staffs are small and staff members have little time to spend in analyzing, in detail, competing products. In the case of the procurement of oils for lubricating purposes, fuel oil, road oiling, or dust control etc., the establishment of federal specifications or guidelines and the Federal Government setting an example by procuring oils according to these standards, would go a long way toward increasing the purchase of recycled oils at the state and local levels of government.

5.3 Proposed Congressional Bills

Two bills introduced to Congressional Committees are aimed at reversing Internal Revenue Service rulings that presently deny re-refiners and consumers of waste oil, a 6¢ per gallon tax credit. As part of the Energy Production and Conservation Tax Incentive Act, the House passed an exemption from the excise tax for new oil used in production, if that oil contains 25% or more re-refined oil and 55% or less virgin oil. The loss of this exemption together with the 1965 Federal Trade Commission labeling requirements severely affects the economics of the recycling industry.

A bill, introduced by Representative Vanik in August 1977, required the use of recycled oil by all federal agencies and their contractors. In addition, it sets up consumer education programs, and makes grants available to states to develop used oil management plans.

5.4 State Used Oil Regulations

Two proposed Illinois regulations, one by Senator Pierce in the General Assembly, and another proposed before the Illinois Pollution Control Board, relates to used oil reuse and disposal. The Waste Oil Recovery Act proposed by Senator Pierce is synopsized as follows:

"Makes the Department of Business and Economic Development responsible for insuring that methods of collecting, storing, transferring and disposing of used oil conform to the requirements of the Act. Requires storage facilities for used oil be maintained by retail outlets and certain industrial users. Sets specific standards for certain oils. Requires the department to conduct public information programs concerning

the use of re-refined oils. Amends an act therein to remove certain labeling requirements for used oil if certain standards are met."

Neither this proposal, nor similar bills proposed to the Assembly, have thus far been able to attract enough support for their passage. These proposals, have in large part, closely paralleled many of the provisions of a model Waste Oil Bill prepared by the Federal Energy Administration in 1976 by members of the Environmental Law Institute.

The Illinois Environmental Protection Agency has proposed a regulation before the Pollution Control Board which, if passed, may have a profound effect on the economics of disposal and reuse of oil. Its scope is broader than just used oil. The special Waste Hauling Regulation (R76-10) is designed to prevent illegal disposal of "special" wastes by haulers. "Special" wastes are considered in three categories: hazardous wastes, pollution control residues and industrial process effluence. The proposed regulation has two principal parts; 1) a permit requirement for special waste haulers, and 2) a manifest system for the generators, haulers and receivers of special wastes.

An annual permit would require information concerning the type of equipment, vehicle capacity, and the type of services offered by haulers. A manifest system would require that a document describing the quantity, composition, and origin, of special wastes, accompany the wastes from the generator to the final storage, treatment, and disposal site.

The manifest system would work in the following manner.

1) The generator would complete the first part of the manifest, identifying the quantity and nature of the special waste.

2) The manifest would accompany the waste shipment and be signed by the hauler and receiver.

3) At the end of each month, the waste hauler, generator, and receiver would be required to submit copies of all manifests to the Illinois Environmental Protection Agency.

The impact of this proposal on used oil is to make it extremely difficult for generators or haulers to dispose of used oil in inexpensive but environmentally unacceptable ways. As the price of disposal rises, the incentive for alternative reuse programs for used oil increases. The Pollution Control Board hearing and review process is still under way regarding the merits of passage of R76-10. Further analysis may be required depending on the outcome of U.S. EPA regulations under RCRA.

5.5 Other State Used Oil Regulations

At present, California has the most comprehensive legislation regarding the recycling of used oils. The California Act, passed in September of 1977, is substantially the same as the FEA Model Act. The California Act prohibits the discharge of used oils to sewers, drainage systems, water courses, marine waters, incineration or deposit on land. The use of used oil for road maintenance, dust control, weed abatement and burning for fuel is not included in the definition of disposal methods requiring special permits. These methods are included in the Model Act.

A California Solid Waste Management Board was established and is required to register oil collectors and recyclers. The Board accepts registrant's applications only if it determines that the applicant's

proposed means for collection, transportation, transfer, storage, recycling, reuse or disposal is operationally safe, environmentally sound and consistent with the provisions of the Act. The Board may require registrants to install controls or institute operating practices which will insure the safe disposal of used oils. Such registration is only required once of the collector or disposer, but the act provides for record-keeping and recording of activities by the collector or recycler on continuous basis. The definition of collector excludes those collecting from sources solely owned and operated by themselves.

The California Act further specifies that the Board adopt rules prescribing means for the provision of safe and conveniently located collection facilities for the deposit of used oil by persons not possessing more than five gallons at one time, at no cost to those persons.

In terms of industrial used oil, some ambiguity exists as to whether the California law regulates the disposal of industrial wastes at all. It clearly covers crankcase type oils, but a requirement that the oils must have been sold to a consumer, may mean that industrial oils are exempted. The omission of used non-recyclable oil from regulation, allows the possibility of unsafe and environmentally hazardous disposal of such oils. Since the fraction of used oil could constitute 50% of the total waste stream, this type of exclusion could have serious consequences.

The Utah Oil ReRefinement Act (1977) is aimed at increasing the amount of oil going to re-refiners. Re-refiners must report on the methods of disposal of re-refined waste products in order to obtain a permit. Both automotive and industrial sources of used oil are required

to dispose of oil only to used oil dealers or re-refiners. Used oil dealers have the option of selling used oil to re-refiners or of disposing of it elsewhere. Other disposal techniques are not regulated in the law.

The Utah law was in part based on legislative findings that disposal practices for used oil constituted an environmental and health hazard.

Fifteen states are at present considering used oil legislative proposals. Most of these are directed toward the same general areas as the Model Act, but they are not as comprehensive. Proposals for the development of storage facilities, public education programs, licensing, and restrictions on dumping are found in many of these bills.

6.0 Industrial Used Oil Policies

The survey of industrial used oil volumes, and their physical and chemical properties indicates that there is a potential for much greater reuse and recovery of oil than is presently practiced. Policies aimed at promoting recovery could be designed in a number of different ways to encourage the generators of used oil, and consumers of recycled oil, toward more conservation oriented actions. Among the desired actions that state policies might seek to promote are:

1) a reexamination of the relative economics of disposal, versus recovery by industries (particularly those impacted by waste-water treatment and solid waste regulations),
2) the segregation of used oil streams within Illinois plants so that the value of such oil is greater to the plant itself and to firms specializing in oil recycling and re-refining,

3) the improvement of the market for recycled or re-refined oil, by seeking to change consumer attitudes toward its use.

Four specific policy initiatives are outlined below which would provide incentives in one or more of these areas. These policies include:

1) an industrial environmental education program aimed at aiding industry in assessing the benefits and costs of oil recovery programs,
2) a state supported chemical testing facility for used oils in order to decrease the initial cost of determing the feasibility of industrial oil recovery,
3) the use of Illinois Energy Bond monies to partially subsidize in-plant demonstrations of used oil recovery systems,
4) the designation of used oil recovery equipment as pollution control equipment, in order to allow faster tax write-offs, and state property tax exemptions,

Each of these options is examined below in terms of the required state action, the mechanism by which the policy would foster industrial used oil recovery, its costs and potential impact.

In order to aid in assessing these policy impacts, an example of an economic analysis of one type of in-plant oil recycling system has been chosen as a benchmark against which to analyze how a firm may react to the implementation of policies presented above.[4] This example is not presented to characterize used oil recycling economics in general, but only to illustrate the relative impact of potential policies.

Figure 6-1 shows the number of years that industrial used oil generators would have to operate an oil filtering recycling system for a "typical oil" in order to pay for the initial purchase price of the system. The payback period varies significantly with the volume of oil involved and the type of use of the recycled product. In general, the most favorable economic conditions for recycling are for large volume users who recycle oil as fuel. This applied only if the oil does not contain high levels of contaminants which may be harmful if emitted to the air and which are difficult to remove, e.g., trace metals. The payback periods for small volume users are not conducive to in-plant recycling with high capital cost equipment, however this oil might be sent to a re-refiner.

The sensitivity of recycling economics to oil volume suggests that, for maximum efficiency, policies be aimed at the education of middle volume users. Partial subsidization of demonstrations of recovery systems should also be directed toward middle volume users, in order to promote an awareness of the benefits of oil conservation practices by the categories of firms most likely to respond to such demonstrations.

6.1 Industrial Education Program

State Action

State action would consist of diseminating information to industries within the state which would aid them in assessing the feasibility and economics of increased industrial oil recovery. The Institute of Natural Resources has already prepared a used oil audit manual which describes the procedure for inventorying oils used in manufacturing processes and the equipment presently available for recovery operations.[5] Distribution

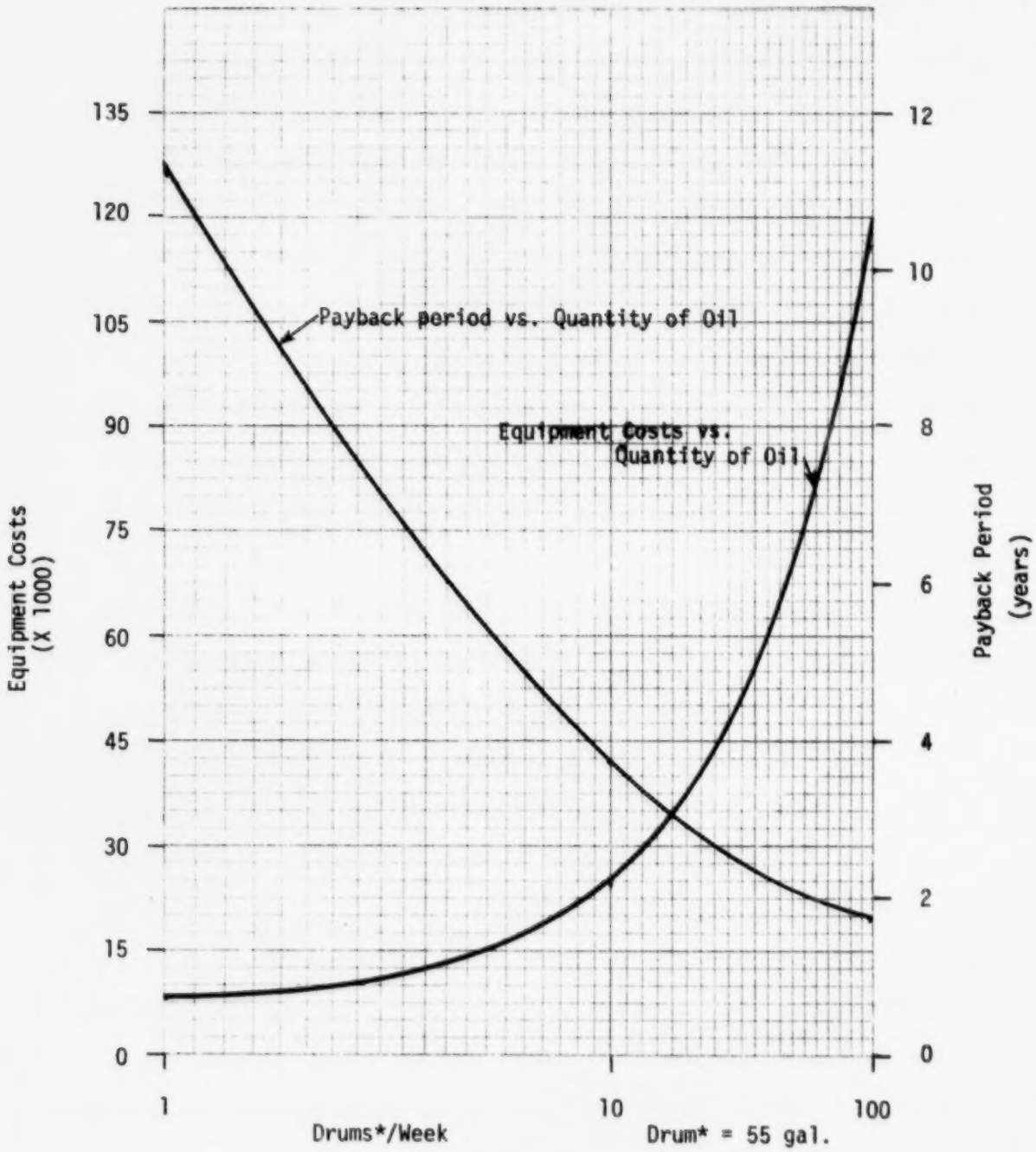

FIGURE 6-1. Equipment Costs and Payback Period vs. Drums of Oils

of the manual would constitute implementation of one phase of an industrial education program.

Mechanism by which Recovery is Encouraged

The manual seeks to draw attention to the potential of industrial oil recovery. Those industries presently facing wastewater and other oily waste problems should be targeted for attention. Significant savings can often be realized in wastewater treatment, investment in other pollution control equipment, and recycling of oils and minimizing oily waste production. The large fraction of unaccounted oil indicated by the survey would suggest that the dissemination of procedural techniques to aid such industries to evaluate investments in recovery equipment would be beneficial.

A major thrust of the manual is in the area of the utilization of in-plant oil segregation, filtering, centrifuging, and settling equipment. Such equipment can be employed to lengthen the life of the oil in the plant or to lower the water and contamination levels of used oil, allowing more economical recovery by professional recycling firms.

Cost and Benefits to Illinois

The cost to Illinois is the development and distribution of the manual. The cost of the manual development has already been incurred, leaving the relatively modest costs of printing and mailing as the only potential future costs required for this policy.

It is difficult to estimate quantitatively the increase in industrial oil recovery due to this educational program.

6.2 State Supported Testing Facility

State Action

This policy would establish, in conjunction with one of the State universities, a laboratory for the testing of industrial used oils as a free service. The model for such a service would be the present testing operation of soils for agriculture. Industries sending in used oil would be given the results of standard chemical and physical tests, possibly with a set of recommendations for further steps to be taken in assessing or improving recovery potential.

Mechanism by which Oil Recovery is Encouraged

While a free testing service does lower the cost of doing a feasibility study of recovery potential, this is not considered to be a significant cost saving. The cost of doing the oil audit within the plant and the cost of subsequent equipment investment would be much greater than initial testing costs. Rather, the mechanism by which the testing service would improve oil recovery is in providing a recognized focus for information regarding the testing, analysis, and recovery techniques for industrial oil. The testing service could be a center for equipment information, a listing of recycling firms, etc. Also, with reliable checks for confidentiality, the centralized testing of oils may indicate which types of firms could most beneficially employ recovery techniques.

Benefits and Costs to the State

The cost of equipment for such a laboratory for all but trace metals tests, does not run more than $10,000. If the laboratory was at a location already having trace metal analysis equipment - as both the

University of Illinois, Urbana, and the University of Illinois, Chicago Circle do - then the equipment might be rented from the University. A research associate and perhaps two graduate students would be sufficient to generate reports for 100 firms per year, as well as, updating equipment inventories, recovery costs, and collating test data.

6.3 Use of Energy Bond Funds to Support Industrial Demonstrations

State Action

State action would be allocation of Energy Bond funds for the support of 25% of industrial recovery projects. The grant would cover only 25% of the initial equipment costs, with the firm receiving the system, paying the remainder.

In order to reap the full benefits of such demonstrations, a group from those receiving such grants could be constituted in a Used Oil Recovery Task Force. The Task Force could report the results of the demonstration in terms of cost savings, technical problems, etc., at the end of the first year's operation.

Mechanism to further recovery

The mechanism in this case is straight forward, since the state is directly paying part of the initial costs of the demonstration systems. Based on the analysis of filtering systems reported by Steele,[4] a reduction of capital cost by 25% would improve the rate of return for firms using 5,000 gallons per year from 9% to 14% for standard lubricants and from 18% to 26% for those recycling to fuel.

This shift would probably provide enough incentive for industries using at least this amount of oil to want to participate. Larger firms

would have higher rates of return based on the economy of scale inherent in such systems.

Benefits and Costs

The cost of the program is based on what is considered to be an appropriate support level of Bond funding. Suppose that one million dollars were allocated to provide 25% of equipment costs for industrial used oil recovery systems. Based on the filtering system cost data, if firms producing 5000 to 50,000 gallons per year of used oil were the main participants in the program, the capital cost would be about 80¢ to $1.00 per gallon. A one million dollar state grant would be matched by three million dollars of private funds so that four million dollars would be invested in systems totally. This is equivalent to an annual four million gallons of recovered industrial oil. This amount would represent a sizable increase in the Illinois industrial recovery rate.

The effectiveness of the policy depends on using the appropriate matching percentage, and attracting firms on the margin of a decision to recover oil. Further investigation may indicate a more appropriate matching percentage.

6.4 Designation of Oil Recovery Equipment as Pollution Control Equipment

State Action

A declaration that oil recovery equipment be granted the same tax status as that of conventional pollution control facilities would be required. In Illinois, Stanley has listed a number of tax advantages afforded to pollution control equipment. These include:

1) a real property tax exemption,

2) a sales-use tax exemption,

3) accelerated depreciation of pollution control equipment,

4) state financial programs for the purchase of pollution control facilities.

In total, these can considerably lower the cost of capital to either the purchaser of an in-plant system, or to a recycling or re-refining specialist.

Conversations with vendors of oil recovery equipment did not yield any clear cut knowledge as to whether oil recovery equipment could be considered pollution control equipment. If a small fraction of oil is separated from water for waste treatment purposes, the equipment is certainly considered pollution control. It would seem reasonable to assume, that the removal of water from oil might also be considered as such. The IRS has ruled in favor of solid waste-energy recovery systems in a number of cases (making the facility eligible for tax exempt financing). There are IRS conditions to be met in order to qualify, but considerable ambiguity exists in this area. A formal ruling on oil recovery equipment as pollution control equipment needs to be sought from the state and federal tax officials.

Mechanism to foster industrial oil recovery

It is difficult to assess the tax benefits of the designation of oil recovery equipment as a pollution control device, without reference to a specific firm's financial situation. The major area of benefit to firms would be derived from considering the accelerated depreciation benefits. A significant benefit will accrue to those specializing in recovery, if their equipment is also considered pollution control equipment, since this is their sole occupation. It would raise their after tax

profit margin, and thereby provide incentives to recover presently marginal oil. This, in turn, would raise the price which they would be willing to pay to used oil generators for the oil.

Benefits and Costs to the State

Deferral of tax revenues would be the major cost to the state, while increased in-plant recovery, and recycling and re-refining by specialists, would be the benefits.

RECOMMENDATIONS

The industrial used oil survey indicates a much greater reuse and recovery potential of oil than currently exists in Illinois. Using the results of the industrial survey, the chemical and physical properties of used oils, and the current state-of-the-art of oil recovery technology, four policies were formulated for consideration by the State of Illinois to encourage increased industrial oil recovery. The policies are: 1) an industrial education program, 2) a state supported used oil testing facility, 3) use of Illinois energy bond monies to subsidize in-plant used oil recovery demonstration systems, and 4) designation of used oil recovery equipment as pollution control equipment.

Of the four possibilities listed, the education program and the designation of used oil recovery equipment as pollution control equipment can be recommended as giving the greatest immediate results with a minimum state investment. The education program would consist of circulating an already prepared industrial plant used oil audit manual and perhaps the development of an industrial short course on recovery methods. Designation of oil recovery equipment as pollution control equipment would allow tax advantages to industries purchasing such equipment. These tax advantages would lower their taxable income by accelerating depreciation rates for recovery equipment.

Subsidizing a state oil testing facility and use of bond monies to subsidize in-plant demonstration recovery units are promising policies but require the state to make some initial capital investment. The state oil testing facility could be established at a State university.

Its function would be to analyze, free of charge, industrial used oils. The cost to the state would be the initial cost of the equipment, plus yearly rental of the more costly specialized analytical instruments owned by the university, and personnel (one research associate and two graduate students to analyze an estimated 500 samples per year). The use of energy bond funds to support industrial demonstrations would consist of grants covering 25% of initial equipment costs for new in-plant oil recovery systems. This would allow marginal plants to participate in recovery programs as well as establishing within the state a task force of participants to evaluate the demonstration project with regard to cost, savings, technical problems, etc. Such an investment by the state would roughly return four gallons of recovered industrial oil for each dollar invested.

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APPENDIX A

Table A-1 - Oil Property Sample Analysis

Table A-2 - Typical Specifications for Some Lubricants

Table A-3 - Comparison of Trace Elements in Virgin Residual Oil and Used Oil

Table A-1

Oil Property Sample Analysis

UI/Motor Oils/ECHO

	Mean	Max.	Min.	Range	Standard* Deviation
API Gravity	28.9	40.6	12.9	27.7	4.85
Ash Content (%)	1.08	14.00	0.03	13.97	2.91
Carbon Residue (%)	0.68	1.90	0.00	1.90	0.51
BS&W (%)	15.1	90.0	0.0	90.0	22.8
Pour Point (^{O}F)	-13.3	59.0	-60.	119.0	30.5
Flash Point (^{O}F)	302	525	140	385	113
Fire Point (^{O}F)	365	600	210	390	119
Viscosity (100^{O}F)	372	2270	30.8	2240	469
Viscosity (210^{O}F)	53.4	145.8	10.8	135	28.3
Acid # (mg koh/g)	1.6	2.0	0.6	1.4	1.1
Heat of Combustion (Btu/lb)	18131	20863	8300	12563	3287

*68% of all observations are within one standard deviation of the mean.
95% of all observations are within two standard deviations of the mean.
99% of all observations are within three standard deviations of the mean.

Table A-2

Typical Specifications for Some Lubricants

Oil	API Gravity	Carbon Residue	Viscosity 100°F	Viscosity 210°F	Ash %	Pour Point (°F)	Flash Point (°F)	Fire Point (°F)	Neutralization #	Water (PPM)
Average Used Oil	28.9	0.68	372	53.4	1.08	-13.3	302	365	1.6	---
Hydraulic Oil	30.0	---	160	---	101	-24	---	---	0.70	---
Rubber Extender Oil	---	---	150	44	---	+15	420	---	0.01	---
Heavey Duty Gear Oil ASTM Grade 215	30.5	---	2.5	48	---	-10	420	---	0.06	---
Heavy Duty Gear Oil ASTM Grade 700	28.5	---	720	76	---	-1	510	---	0.08	---
Transformer Oil	---	---	60	---	---	-75	310	---	0.00	25
Steam Turbine*	31.8	0.0	150	43.6	nil	0	405	460	0.3	---
Textile Spindles*	33.4	nil	73	36	nil	-5	340	380	0.3	---
Cylinder (Steam)*	25.8	0.7	2130	140	nil	15	555	630	0.06	---
Cutting Sulfur*	29.9	0.3	89.2	39.1	nil	15	345	380	0.60	---
General Lubricating*	59-3550	---	---	---	nil	---	0-105	---	---	---

* Source: Handbook of Engineering Fundamentals, Eshback, 1961.

Table A-3

Trace Element Sample Analysis

Sample	Mean	Standard* Deviation	Max.	Min.	Range
Sulfur	0.44	0.31	1.4	0	1.4
Silver	0.10	0.15	0.6	0	0.6
Sodium	46.6	97.3	400	0	400
Zinc	219.4	635.2	5000	0.7	4999.3
Copper	58.3	166	1160	0	1160
Aluminum	67.1	327	2000	1.0	1999
Barium	59.7	98.5	550	0	550
Nickel	6.4	10.2	44	0	44
Chromium	7.9	8.6	45	0	45
Calcium	316	960	6400	0	6400
Iron	333	794	5100	1	5099
Silicon	104	370	2500	1	2499
Tin	12.5	25.5	140	0	140
Lead	125	331	2000	0.4	1999.6
Phosphorous	307	482	2500	0	2500
Boron	7.3	22.1	120	0	120
Magnesium	49.4	178	1000	0	1000
Vanadium	5.2	4.3	19	0	19
Molybdenum	2.2	4.2	19	0	19
Manganese	21	45	250	0	250
Cadmium	2.7	4.1	21	0	21
Titanium	6.5	19.8	110	0	110

*68% of all observations are within one standard deviation of the mean.
95% of all observations are within two standard deviations of the mean.
99% of all observations are within three standard deviations of the mean.

APPENDIX B

Table B-1 - Grades and Types of Fuel Oils

TABLE B-1: GRADES AND TYPES OF FUEL OILS

Grade of Fuel Oil	Flash Point deg F (deg C)	Pour Point deg F (deg C)	Water and Sediment percent by vol	Carbon Residue on 10 percent Bottoms, percent	Ash percent by weight	Distillation Temperatures deg F (deg C)			Saybolt Viscosity, sec				Kinematic Viscosity centistokes				Gravity deg API	Copper Strip Corrosion
						10 percent point	90 percent point		Universal at 100°F (38°C)		Furol at 122°F (50°C)		At 100°F (38°C)		At 122°F (50°C)			
	Min	Max	Max	Max	Max	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
No. 1 A distillate oil intended for vaporizing pot-type burners and other burners requiring this grade of fuel	100 or legal (38)	0	trace	0.15	--	420 (215)	--	550 (288)	--	--	--	--	1.4	2.2	--	--	35	No.3
No. 2 A distillate oil for general purpose domestic heating for use in burners not requiring No. 1 fuel oil	100 or legal (38)	20[c] (-7°)	0.10	0.35	--	[d]	540[e] (282)	640 (338)	(32.6)[f]	(37.93)	--	--	2.0[e]	3.6	--	--	30	--
No. 4 Preheating not usually required for handling or burning	130 or legal (55)	20 (-7)	0.50	--	0.10	--	--	--	45	125	--	--	(5.8)	(26.4)	--	--	--	--
No. 5 Preheating may be required depending on climate and equipment	130 or legal (55)	--	1.00	--	0.10	--	--	--	150	300	--	--	(32)	(65)	--	--	--	--
No. 5 (heavy) Preheating may be required for burning and, in cold climates, may be required for handling	130 or legal (55)	--	1.00	--	0.10	--	--	--	350	750	(23)	(40)	(75)	(162)	(42)	(81)	--	--
No. 6 Preheating required for burning and handling	150 (65)	--	2.00[g]	--	--	--	--	--	(900)	(9000)	45	300	--	--	(92)	(638)	--	--
* Used Oil Range	140 to 525	-60 to 59	0 to 90	0 to 1.9	0.03 to 14.0				31	2270								
Sulfur Content 0 - 1.4%																		

a Recognizing the necessity for low-sulfur fuel oils used in connection with heat-treatment, nonferrous metal, glass, and ceramic furnaces and other special uses, a sulfur requirement may be specified in accordance with the following table:

Grade of Fuel Oil	Sulfur, max, percent
No. 1	0.5
No. 2	0.7
No. 4	no limit
No. 5	no limit
No. 6	no limit

Other sulfur limits may be specified only by mutual agreement between the purchaser and the seller.

b It is the intent of these classifications that failure to meet any requirement of a given grade does not automatically place an oil in the next lower grade unless in fact it meets all requirements of the lower grade.

c Lower or higher pour points may be specified whenever required by conditions of storage or use.

d The 10 percent distillation temperature point may be specified at 440°F (226°C) maximum for use in other than atomizing burners.

e When pour point less than 0°F is specified, the minimum viscosity shall be 1.8cs (32.0 sec, Saybolt Universal) and the minimum 90 percent point shall be waived.

f Viscosity values in parentheses are for information only and not necessarily limiting.

g The amount of water by distillation plus the sediment by extraction shall not exceed 2.00 percent. The amount of sediment by extraction shall not exceed 0.50 percent. A deduction in quantity shall be made for all water and sediment in excess of 1.0 percent.

* Laboratory data see Reference 1

Source: ASTM Designation: D396-67, Book of ASTM Standards.

APPENDIX C

Table C-1 - Trace Element Sample Analysis

Table C-1

Comparison of Trace Elements in Virgin Residual Oil and Used Oil

Element (Product)	Residual Oil* PPM (Median)	Used Oil PPM (Median)	Ratio $\frac{\text{Used}}{\text{Residual}}$
Sulfur	12000	0.44	4×10^{-5}
Silver	0.20	0.10	0.50
Sodium	35	46.6	1.33
Zinc	4	219	54.8
Copper	2.5	58.3	23.3
Aluminum	75	67.1	0.89
Barium	4	59.7	15
Nickel	120	6.4	0.05
Chromium	3	7.9	2.6
Calcium	120	316	2.6
Iron	150	333	2.2
Silicon	300	104	0.35
Tin	0.3	12.5	41.7
Lead	2	125	62.5
Phosphorous	4	307	76.8
Boron	0.3	7.3	24.3
Magnesium	75	49.4	0.66
Vanadium	180	5.2	0.03
Molybdenum	0.25	2.2	8.8
Manganese	2.5	21.0	8.4
Cadmium	0.2	2.7	13.5
Titanium	0.4	6.5	16.3

*Source: Power Engineering, January 1976.